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An Intelligent Neutrosophic Type-II Model for Selecting Optimal Internet of Things (IoT) Service Provider: Analysis and Application

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Abstract: The Internet of Things, or IoT, is a rapidly expanding technology, and one of its most important application areas is sustainable transportation. Choosing the right IoT service provider is a complex process that is considered a multi-criteria decision issue. The multi-criteria decision-making (MCDM) methodology deals with massive criteria. This study proposed an MCDM methodology for selecting the best IoT service provider under different sustainable criteria. The Multi-Objective Optimization Ratio Analysis (MOORA) method is an MCDM methodology used to rank the alternatives. The MOORA method is integrated with a type 2 neutrosophic set to deal with uncertain information. The proposed MCDM methodology applied to six criteria and 13 alternatives. The results show that alternative 3 is the best and alternative 5 is the worst. The sensitivity analysis was conducted to show the stability of the rank. The sensitivity analysis was performed under seven cases; the results show that the rank of alternatives was stable under different cases. The comparative study was conducted to show the effectiveness of the proposed methodology.

Keywords: Internet of Things; Soft Computing; MCDM; Neutrosophic Logic; IoT Services; Artificial Intelligence.

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1. Introduction

The Internet of Things, or IoT, is a network of different things with sensors installed. These items generate and send data to the cloud for processing, which allows for the inference of essential information for making decisions. Following cloud computing and services computing, it is the next emerging paradigm since the user may more efficiently use the diverse capabilities of the Internet of Things based on service-oriented computing. Many large corporations, like Microsoft, IBM, Cisco, Samsung, and Nokia, are investing in technology advancement to establish IoT services and make them viable for their clients. The increasing number of devices with sensors, the widespread availability of high-speed Internet, the decreased cost of device connections to the Internet, etc., are the main factors contributing to the market of IoT[1].

As the Internet of Things grows and expands, many new IoT service providers are jumping on board to provide a wide range of these services. These providers assert that their case studies, which include several noteworthy customer references, provide stronger support. A service's quality might differ depending on the application. A service's ability to satisfy customer needs effectively determines its success. Defining and identifying their needs to choose an appropriate service can be difficult for users. Users can recognize their needs and evaluate the characteristics of various services to select the best option from those offered with an efficient tool or set of recommendations. An IoT customer may wind up paying more than necessary in addition to vendor lock-in if quality of service (QoS) criteria connected to IoT are thoroughly described in one location. This is something that can be beneficial[2].

Understanding QoS metrics in IoT requires exploring the different components involved in IoT application development. To illustrate this, let's consider one of the most popular IoT applications—the smart home. In a smart home, several sensor-equipped household equipment run without human input. These devices make wise decisions, such as adjusting the air conditioner's temperature based on the weather, controlling the lights based on the number of people, and using motion detection for security. This not only enhances the home's functionality but also gives the owner peace of mind[3], [4].

The following are this application's four primary components: The first element consists of a network of different sensors, such as temperature sensors, that are either independently operating or connected to the appliances to perceive data from the surroundings. The information transmission is the second element. Sensors may be linked to a local hub that securely transmits and stores the data after it's been gathered, analyzed, and stored. If necessary, it can also send an alarm to the owner's family members. The third element is an interface allowing users to control the household's gadgets and get notifications. The last part is service management, which handles the service providers' billing, upgrading, and other activities. From the preceding, it is clear that the three main components of nearly all Internet of objects applications are computation, communication, and objects. To comprehend IoT services, one must have access to QoS data about every component. Because IoT infrastructure requires a significant amount of hardware and software, experts predict it is impractical for one business to provide an end-to-end IoT solution. However, significant participants may work together to create quicker, more effective, and more affordable solutions by enhancing one another's technological and commercial expertise[5], [6].

When a service comprises several sub-services, users or organizations require sub-service specialists to help them make the best possible decisions about which services to choose. IoT support is, therefore, only valid when the best and most practical IoT services are chosen through the integration and assessment of computing, communication, and object services. For these three services, the computing service provider (CSP), communication service provider (CSP), and Internet of Things service provider (IoTSP) are the accountable providers, in that order[7], [8].

The opinions of many decision-makers (DMs) or experts must be merged to determine the best choice in this kind of selection setting. Multi-criteria group decision-making difficulties are another name for these kinds of dilemmas. The goal of designing a group decision-making model is to give DM preferences a solid mathematical foundation so they can pick the best option out of those offered while considering the significance of different KPIs. The multi-criteria decision-making (MCDM) methodology is used to deal with various criteria. MCDM methodology is applied in various applications such as assessment of health sustainability [9], sustainability energy [10], supplier selection supply chain management [11], construction [12], cloud platform selection for smart framing [13], in bioenergy systems [14], in agriculture [15], in financial decision making [16], selecting optimal charcoal company [17].

DM has to deal with a variety of unknowns. Zadeh [18]created fuzzy set theory, which is widely used to address uncertainty. However, because it is hard to give a precise membership value, fuzzy set theory does not always account for all uncertainties. Zadeh [19]addressed this restriction by introducing the idea of type-2 fuzzy sets (T2FS). The fuzzy set was applied in various real-life applications such as solar hydrogen production [20], improvement projects [21], and blockchain technology strategies assessment [22]. However, in many real-world applications, the uncertainty is predicated on both indeterminacy grades and membership and non-membership degrees. Smarandache [23], [24]created the idea of neutrosophic sets (NS) to remedy this. Neutrosophic sets were applied in various applications such as the evaluation of solar power plants [25] and construction projects [26].

Brauers invented the Multi-Objective Optimisation Ratio Analysis (MOORA) method, which is regarded as an objective (non-subjective) approach. In addition, ranking is done using both desired and unwanted criteria at the same time to choose a higher or better option from the group of alternatives. There are a lot of uses for this method[27], [28]. The following characteristics of the MOORA approach are:

- *It is a component of compensating techniques.*
- *Features stand alone;*
- *The process transforms the qualitative characteristics into quantitative ones.*

2. Preliminaries

This section introduces some concepts of neutrosophic type 2 and their operations[29].

Definition 1.

Let x be the limited universe of discourse and F[0,1] be the set of all triangular neutrosophic numbers on F[0,1]. A type 2 neutrosophic number set (T2NNS) A in X is represented by $A = \{x, T_A(x), I_A(x), F_A(x) |\, x \in X\}$, where $T_A(x): X \to F[0,1], I_A(x): X \to F[0,1], and\ F_A(x): X \to F[0,1]$. A T2NNS

$T_A(x) = \left(T_{T_A}(x), T_{I_A}(x), T_{F_A}(x)\right), I_A(x) = \left(I_{T_A}(x), I_{I_A}(x), I_{F_A}(x)\right), and\ F_A(x) = \left(F_{T_A}(x), F_{I_A}(x), F_{F_A}(x)\right)$ refers to the truth, indeterminacy, and falsified membership degrees.

$0 \leq T_A(x)^3 + I_A(x)^3 + F_A(x)^3 \leq 3$

$A = \left(\left(T_{T_A}(x), T_{I_A}(x), T_{F_A}(x)\right), \left(I_{T_A}(x), I_{I_A}(x), I_{F_A}(x)\right), \left(F_{T_A}(x), F_{I_A}(x), F_{F_A}(x)\right)\right)$ as a T2NNS.

Definition 2.

$$let\ A_1 = \begin{pmatrix} \left(T_{T_{A_1}}(x), T_{I_{A_1}}(x), T_{F_{A_1}}(x)\right), \\ \left(I_{T_{A_1}}(x), I_{I_{A_1}}(x), I_{F_{A_1}}(x)\right), \\ \left(F_{T_{A_1}}(x), F_{I_{A_1}}(x), F_{F_{A_1}}(x)\right) \end{pmatrix} \text{ and } A_2 = \begin{pmatrix} \left(T_{T_{A_2}}(x), T_{I_{A_2}}(x), T_{F_{A_2}}(x)\right), \\ \left(I_{T_{A_2}}(x), I_{I_{A_2}}(x), I_{F_{A_2}}(x)\right), \\ \left(F_{T_{A_2}}(x), F_{I_{A_2}}(x), F_{F_{A_2}}(x)\right) \end{pmatrix} \quad (1)$$

The sum of two T2NNS is:

$$A_1 \oplus A_2 = \begin{pmatrix} \begin{pmatrix} \left(T_{T_{A_1}}(x) + T_{T_{A_2}}(x) - T_{T_{A_1}}(x) T_{T_{A_2}}(x)\right) \\ \left(T_{I_{A_1}}(x) + T_{I_{A_2}}(x) - T_{I_{A_1}}(x) T_{I_{A_2}}(x)\right), \\ T_{F_{A_1}}(x) + T_{F_{A_2}}(x) - T_{F_{A_1}}(x) T_{F_{A_2}}(x) \end{pmatrix}, \\ \left(I_{T_{A_1}}(x) I_{T_{A_2}}(x), I_{I_{A_1}}(x)\, I_{I_{A_2}}(x), I_{F_{A_1}}(x) I_{F_{A_2}}(x)\right), \\ \left(F_{T_{A_1}}(x) F_{T_{A_2}}(x), F_{I_{A_1}}(x) F_{I_{A_2}}(x), F_{F_{A_1}}(x) F_{F_{A_2}}(x)\right) \end{pmatrix} \quad (2)$$

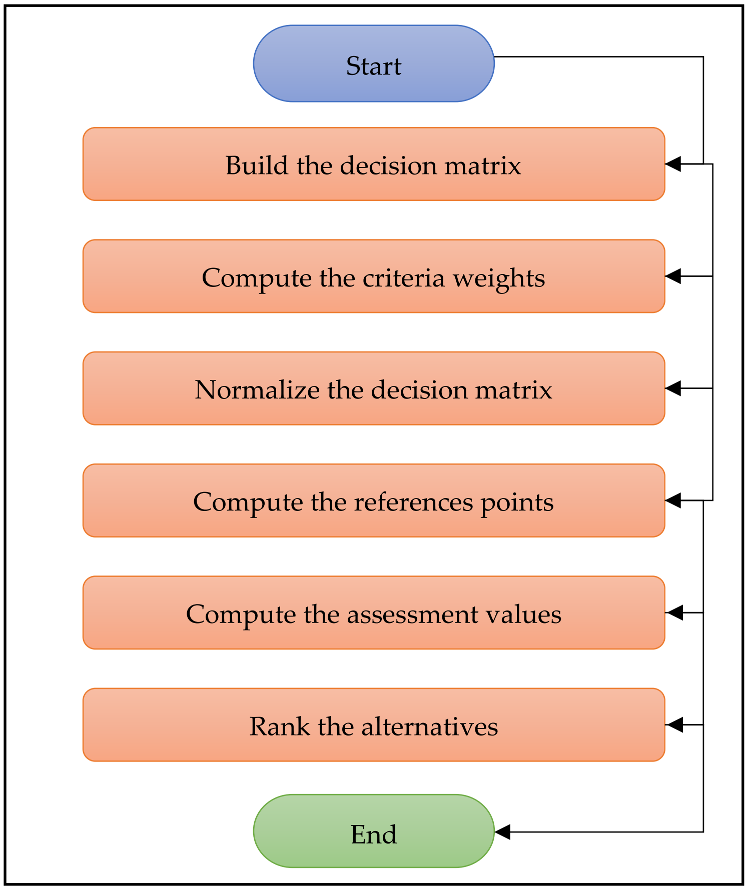

Figure 1. The steps of the proposed method.

Definition 3.

The multiplication of two T2NNS is:

$$A_1 \otimes A_2 = \begin{pmatrix} \left(T_{T_{A_1}}(x)T_{T_{A_2}}(x), T_{I_{A_1}}(x)\,T_{I_{A_2}}(x), T_{F_{A_1}}(x)T_{F_{A_2}}(x)\right), \\ \begin{pmatrix} \left(I_{T_{A_1}}(x) + I_{T_{A_2}}(x) - I_{T_{A_1}}(x)I_{T_{A_2}}(x)\right) \\ \left(I_{I_{A_1}}(x) + I_{I_{A_2}}(x) - I_{I_{A_1}}(x)I_{I_{A_2}}(x)\right), \\ I_{F_{A_1}}(x) + I_{F_{A_2}}(x) - I_{F_{A_1}}(x)I_{F_{A_2}}(x) \end{pmatrix}, \\ \begin{pmatrix} \left(F_{T_{A_1}}(x) + F_{T_{A_2}}(x) - F_{T_{A_1}}(x)F_{T_{A_2}}(x)\right) \\ \left(F_{I_{A_1}}(x) + F_{I_{A_2}}(x) - F_{I_{A_1}}(x)F_{I_{A_2}}(x)\right), \\ F_{F_{A_1}}(x) + F_{F_{A_2}}(x) - F_{F_{A_1}}(x)F_{F_{A_2}}(x) \end{pmatrix} \end{pmatrix} \quad (3)$$

3. Materials and Methods

This section presents the MCDM methodology to compute the weights of criteria and rank the alternatives under T2NSs to deal with vague information. Figure 1 shows the proposed MCDM methodology under

T2NSs. This study uses the MOORA method to rank the alternatives. The following are the steps of the proposed MCDM methodology:

Step 1. Build the decision matrix between criteria and alternatives.

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}_{m\times n} ; i = 1,2, \dots , m, \quad j = 1,2, \dots , n \quad (4)$$

Experts used T2NNS to evaluate the criteria and alternatives. Then we obtain the crisp values, then we combine these matrices into one matrix.

Step 2. Compute the criteria weights.

$$\sum_{j=1}^{n} w_j = 1 \quad (5)$$

Step 3. Normalize the decision matrix.

$$x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (6)$$

Step 4. Compute the reference points.

Step 5. Compute the assessment values.

$$u_i = \sum_{j=1}^{g} x_{ij}^* w_j - \sum_{j=g+1}^{n} x_{ij}^* w_j \quad (7)$$

Where g refers to the number of positive criteria and n-g refers to the number of negative criteria.

Step 6. Rank the alternatives in descending order based on the value of u_i.

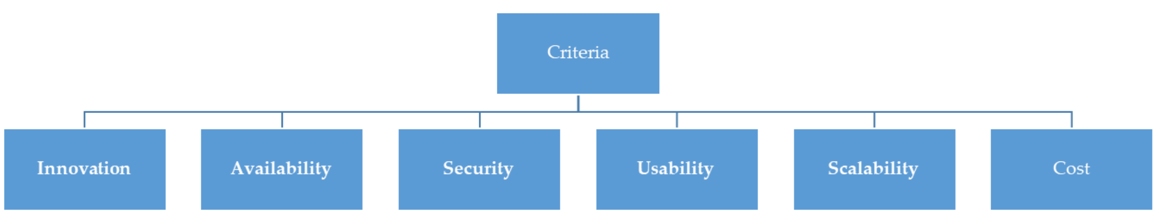

Figure 2. A group of criteria.

4. Results

This section presents the results of the proposed methodology for selecting the best IoT service provider. Three experts have experience in the industry and academic degrees to evaluate the criteria and alternatives. They used linguistic terms to evaluate the criteria and alternatives to their opinions. Then we used the T2NNS to evaluate the criteria and alternatives. This study used 6 criteria and 13 alternatives as shown in Figure 2.

Step 1. Eq. (4) was used to build the decision matrices between criteria and alternatives as shown in Tables A1-A3. We used the score function to obtain the crisp values[30]. Then we used the aggregated method to combine these matrices.

Step 2. We compute the weights of the criteria as shown in Figure 3. We show that criterion 6 has the highest weight and criterion 2 has the lowest weight.

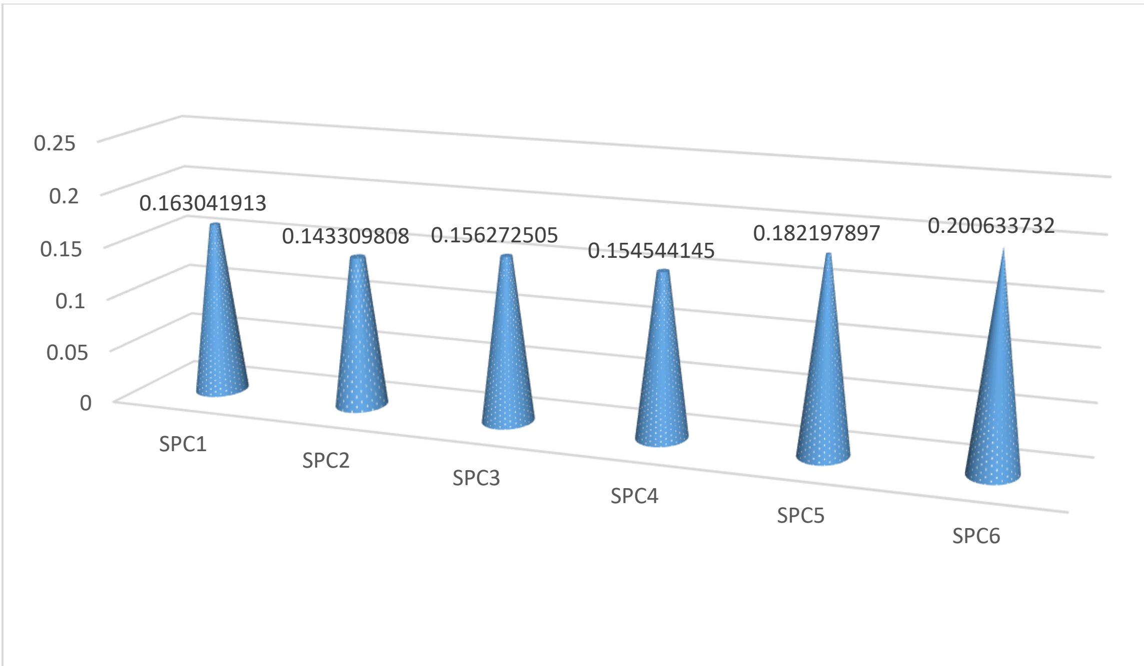

Figure 3. The criteria weights.

Table 1. Normalization decision matrix.

	SPC_1	SPC_2	SPC_3	SPC_4	SPC_5	SPC_6
SPA_1	0.270784	0.198809	0.214399	0.242543	0.308194	0.239285
SPA_2	0.305979	0.260247	0.243459	0.198733	0.261438	0.300217
SPA_3	0.236308	0.227802	0.242813	0.240004	0.263413	0.344647
SPA_4	0.275094	0.260247	0.243459	0.284449	0.322681	0.285619
SPA_5	0.173819	0.425231	0.3978	0.297147	0.275925	0.208819
SPA_6	0.339737	0.304426	0.217627	0.351751	0.221926	0.166928
SPA_7	0.390016	0.211925	0.227314	0.299687	0.142902	0.213262
SPA_8	0.300951	0.216067	0.302224	0.333973	0.21995	0.311007
SPA_9	0.317471	0.259556	0.316432	0.266036	0.279218	0.371305
SPA_{10}	0.344047	0.276124	0.349366	0.208892	0.35034	0.404944
SPA_{11}	0.221943	0.310639	0.125281	0.13778	0.290413	0.213897
SPA_{12}	0.172383	0.325826	0.227314	0.333973	0.346389	0.182796
SPA_{13}	0.122823	0.248511	0.371969	0.323815	0.252877	0.23992

Step 3. Eq. (6) used to normalize the decision matrix as shown in Table 1.

Step 4. Compute the reference points. Then compute the weighted normalized decision matrix as shown in Table 2.

Table 2. Weighted normalization decision matrix.

	SPC_1	SPC_2	SPC_3	SPC_4	SPC_5	SPC_6
SPA_1	0.044149	0.028491	0.033505	0.037484	0.056152	0.048009
SPA_2	0.049887	0.037296	0.038046	0.030713	0.047633	0.060234
SPA_3	0.038528	0.032646	0.037945	0.037091	0.047993	0.069148
SPA_4	0.044852	0.037296	0.038046	0.04396	0.058792	0.057305
SPA_5	0.02834	0.06094	0.062165	0.045922	0.050273	0.041896
SPA_6	0.055391	0.043627	0.034009	0.054361	0.040434	0.033491
SPA_7	0.063589	0.030371	0.035523	0.046315	0.026036	0.042788
SPA_8	0.049068	0.030964	0.047229	0.051614	0.040074	0.062399
SPA_9	0.051761	0.037197	0.04945	0.041114	0.050873	0.074496
SPA_{10}	0.056094	0.039571	0.054596	0.032283	0.063831	0.081246
SPA_{11}	0.036186	0.044518	0.019578	0.021293	0.052913	0.042915
SPA_{12}	0.028106	0.046694	0.035523	0.051614	0.063111	0.036675
SPA_{13}	0.020025	0.035614	0.058128	0.050044	0.046074	0.048136

Step 5. Eq. (7) is used to compute the assessment values as shown in Figure 4.

Step 6. Rank the alternatives in descending order based on the value of u_i as shown in Figure 5. Alternative 3 is the best and alternative 5 is the worst.

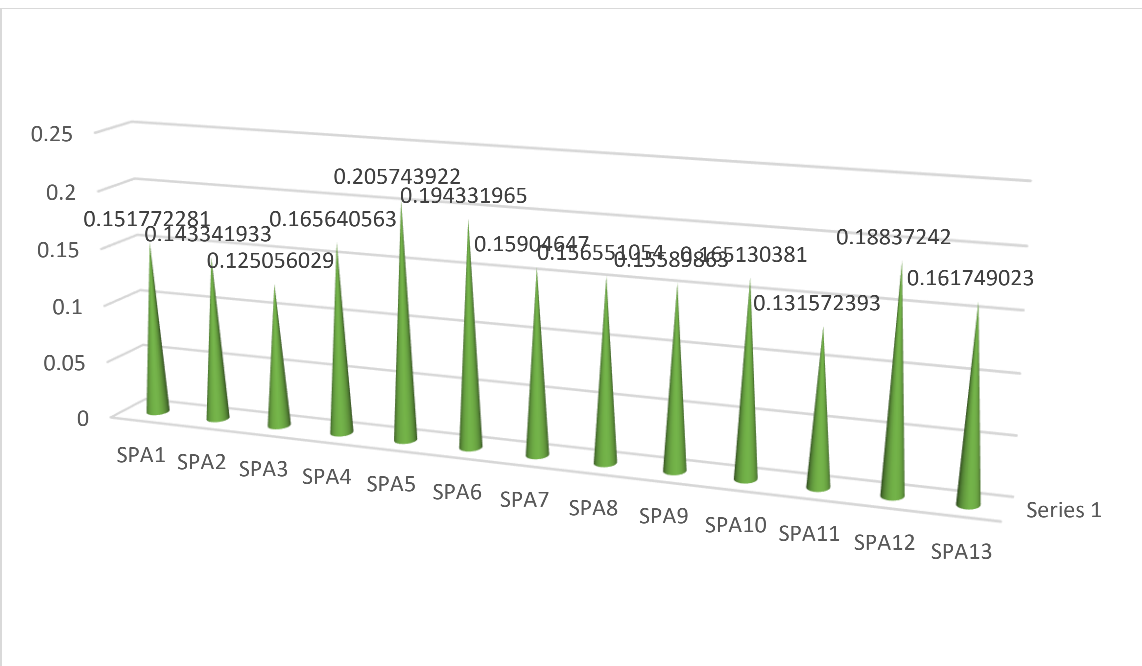

Figure 4. The assessment values.

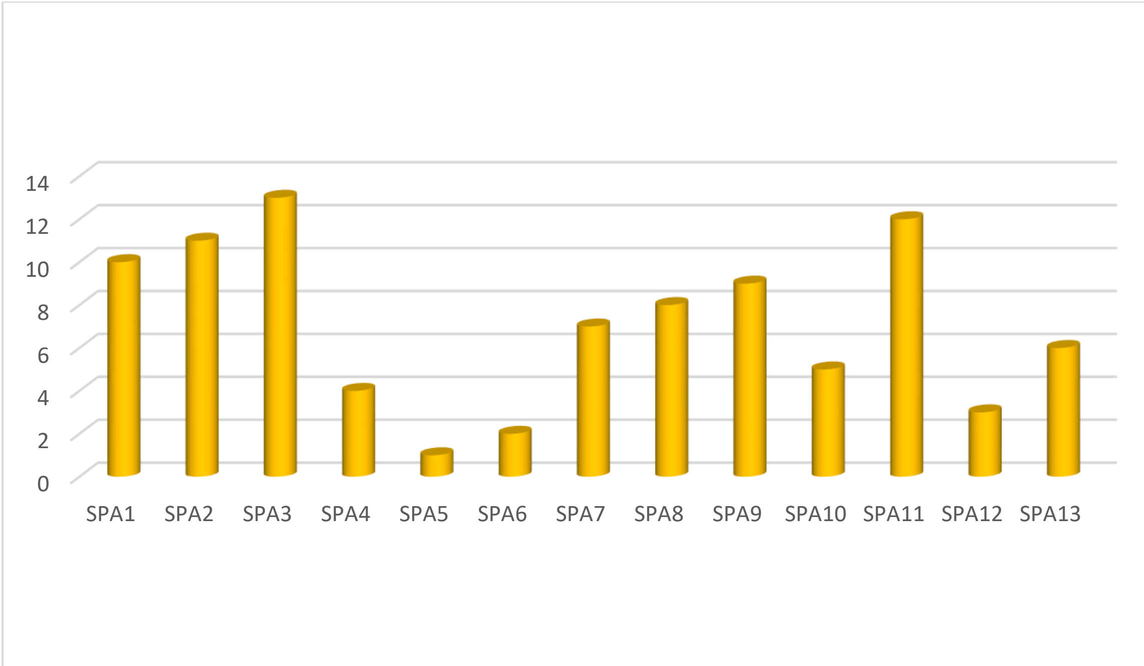

Figure 5. The rank of alternatives.

5. Sensitivity analysis

This section presents the sensitivity analysis to ensure the stability of the rank. We changed the weights of the criteria, then we applied the MOORA method. The weights of the criteria are changed under different seven cases as shown in Figure 6. In the first case, the equal weights are determined. In the second case, the first criterion weighs 0.2, and other criteria have the same weight.

We applied the MOORA method under different seven cases. We show the rank of alternatives is stable under different cases. All cases have alternative 5 as the worst and alternative 3 as the best except cases 4 and 5. Cases 4 and 5 have alternative 11 is the best and alternative 5 is the worst. Figure 7 shows the rank of alternatives.

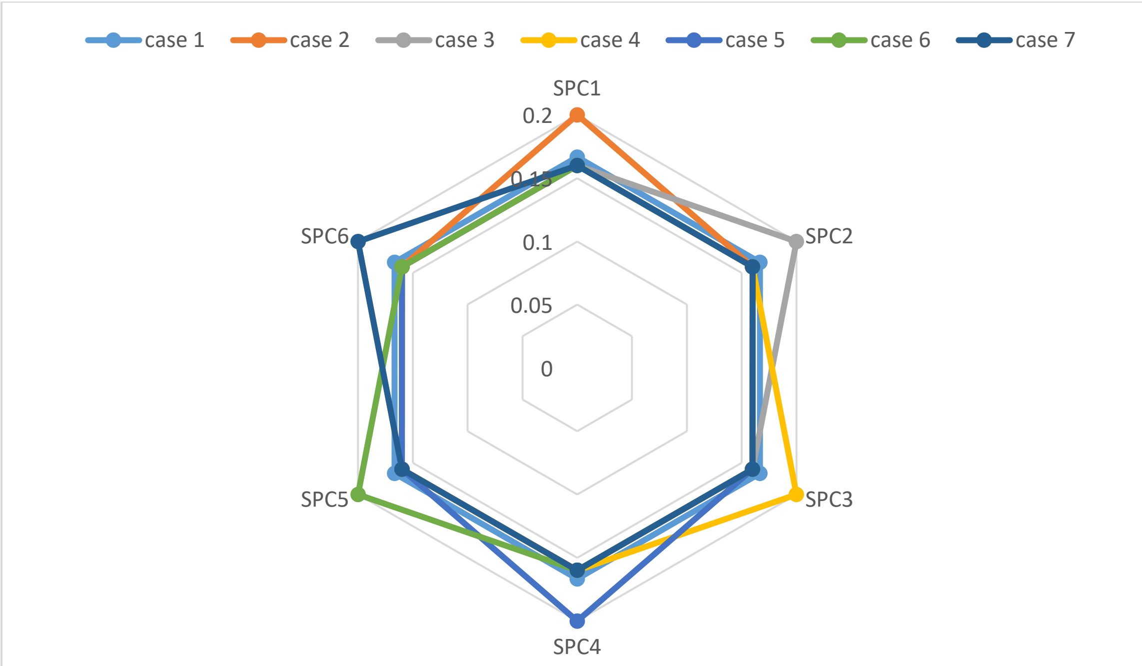

Figure 6. Criteria weights under sensitivity analysis.

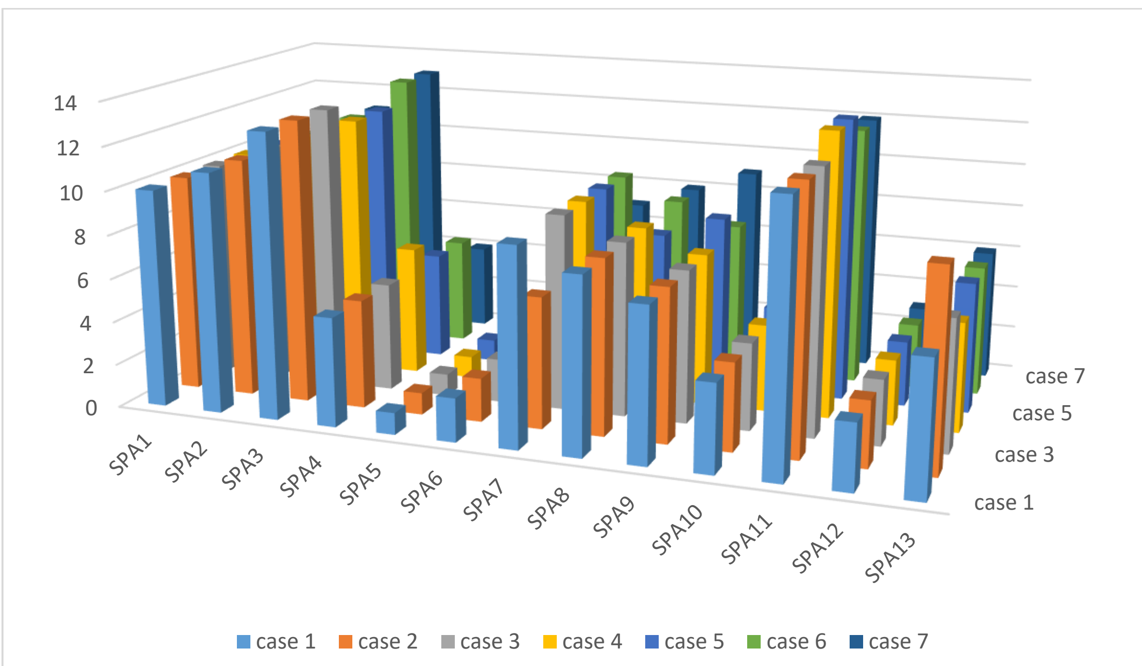

Figure 7. The rank of alternatives under different cases.

6. Comparative analysis

We compared the proposed methodology with other MCDM methods such as TOPSIS, VIKOR, MABAC, and WASPAS to show the effectiveness of the proposed methodology. Figure 8 shows the rank of alternatives under comparison study. Alternative 3 is the best in all comparative studies and alternative 5 is the worst. So the proposed method is effective compared with other MCDM methods.

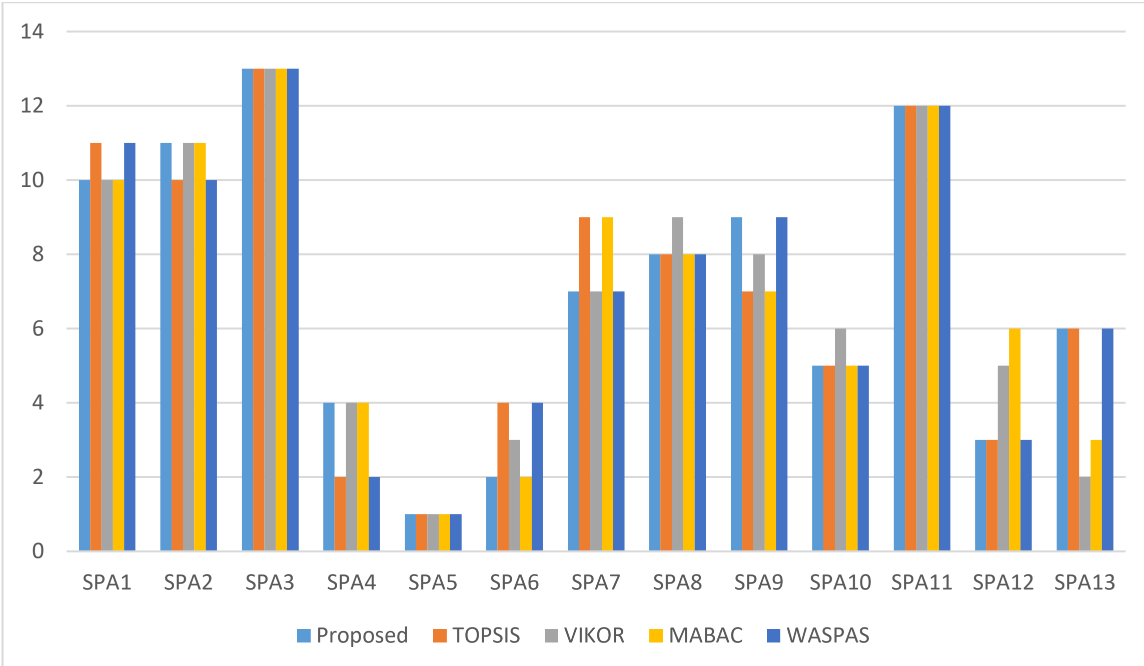

Figure 8. The rank of alternatives under comparative study.

We compute the correlation coefficient between the proposed methodology with other compared MCDM methods as shown in Table 3. We show the correlation between the proposed methodology and WASPAS is the highest and the correlation between the proposed methodology and the MABAC method is the lowest.

Table 3. The correlation between the proposed methodology and comparison MCDM methods.

	Proposed	TOPSIS	VIKOR	MABAC	WASPAS
Proposed	1	0.950549	0.934066	0.928571	0.972527
TOPSIS	0.950549	1	0.906593	0.923077	0.978022
VIKOR	0.934066	0.906593	1	0.972527	0.917582
MABAC	0.928571	0.923077	0.972527	1	0.901099
WASPAS	0.972527	0.978022	0.917582	0.901099	1

7. Organizational Impactions

This paper applied the MCDM methodology for selecting optimal IoT service providers. The MOORA method was used to rank the alternatives. The MOORA method was integrated with a neutrosophic set to deal with uncertain information. The proposed methodology can help managers select the best criteria for selecting IoT service providers. The proposed method can be applied in various organizations and firms. The proposed method is beneficial for selecting IoT service providers in intelligent cities.

8. Conclusions

This study proposed an MCDM methodology for ranking and selecting the best IoT service provider based on criteria and alternatives. The MOORA method was used to rank the other options. The neutrosophic set was integrated with MCDM methodology to deal with uncertain information. Three experts are invited to evaluate the criteria and alternatives. Then, we used the type 2 neutrosophic numbers to assess the requirements and alternatives. We applied the score function to obtain the crisp values. Then, we combine these matrices into one matrix. Then, we compute the weights of the criteria. The results show that criterion 6 has the highest and criterion 2 has the lowest. The MOORA method was applied based on the weights of the criteria. The results show that alternative 3 is the best and alternative 5 is the worst. The sensitivity analysis was conducted to show the stability rank of alternatives. There are seven cases created to change the weights of criteria. The sensitivity analysis results show that alternative 3 is the best and alternative 5 is the worst, so the rank of alternatives is stable in different cases. The proposed methodology was compared with four MCDM methods: TOPSIS, VIKOR, MABAC, and WASPAS. The results show that the proposed methodology is effective compared with other MCDM methods. The proposed methodology can be applied to different decision-making methodologies in future research. Other MCDM methods can be used for this problem.

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Appendix

Table A1. The first decision matrix.

	SPC1	SPC2	SPC3	SPC4	SPC5	SPC6
SPA1	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))
SPA2	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))
SPA3	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))
SPA4	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))
SPA5	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))
SPA6	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))
SPA7	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))
SPA8	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))
SPA9	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))
SPA10	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))
SPA11	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))
SPA12	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))
SPA13	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))

Table A2. The second decision matrix.

	SPC1	SPC2	SPC3	SPC4	SPC5	SPC6
SPA1	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))
SPA2	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))
SPA3	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))
SPA4	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))
SPA5	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))
SPA6	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))
SPA7	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))
SPA8	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))
SPA9	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))
SPA10	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))
SPA11	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))
SPA12	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))
SPA13	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))

Table A3. The third decision matrix.

	SPC_1	SPC_2	SPC_3	SPC_4	SPC_5	SPC_6
SPA_1	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))
SPA_2	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))
SPA_3	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))
SPA_4	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))
SPA_5	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))
SPA_6	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))
SPA_7	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))
SPA_8	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))
SPA_9	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))
SPA_{10}	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))
SPA_{11}	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))
SPA_{12}	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.95,0.90,0.95),(0.10,0.10,0.05),(0.05,0.05,0.05))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))
SPA_{13}	((0.20,0.20,0.10),(0.65,0.80,0.85),(0.45,0.80,0.70))	((0.35,0.5,0.10),(0.50,0.75,0.80),(0.50,0.75,0.65))	((0.70,0.75,0.80),(0.15,0.20,0.25),(0.10,0.15,0.20))	((0.60,0.45,0.50),(0.20,0.15,0.25),(0.10,0.25,0.15))	((0.40,0.45,0.50),(0.40,0.45,0.50),(0.35,0.40,0.45))	((0.50,0.30,0.50),(0.50,0.35,0.45),(0.45,0.30,0.60))

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